Multiple Planets with SIM

Xiaopei Pan

Jet Propulsion Laboratory
California Institute of Technology
Feb. 22, 2008

Key Issues

- Can we detect true Earth-like planets for nearby G, K stars? i.e. habitable, imageable and spectrally observable for further studies.
- Can we detect the Earth-like planets with a Jupiter?
- Can we detect the Earth-like planets in a solar planetary system?

Multiple Planet Systems Discovered

- About 24% exoplanets are in multiple planet system
- About 11% exoplanet systems have more than one planet
- Maximum number of components in a exoplanet system is 5.
- Most of exoplanets have minimum mass only

Current Multiple Planets

55 Cancri distan(pc) 12.5 massSun 0.942

axis (AU)	period (day)	eccentricity	mass (in Jupiter)	signature (μas)	RV_sig (m/s)
0.038	2.82	0.070	0.034	0.105	5.070
0.115	14.65	0.014	0.824	7.677	71.322
0.240	44.34	0.086	0.169	3.288	10.123
0.781	260	0.200	0.144	9.118	4.868
5.770	5218	0.025	3.835	1787.328	46.777

ups And distan(pc) 64.56 massSun 1.32

axis (AU)	period (day)	eccentricity	mass (in Jupiter)	signature (μas)	RV_sig (m/s)
0.060	4.6	0.022	0.69	0.457	69.586
0.832	241.3	0.258	1.98	18.431	55.606
2.550	1296.0	0.267	3.97	113.098	63.785

Complicated Solar System

- The solar system has 8 planets
- The solar system has wide rage of periods from 0.2 to 164 yrs
- The masses of the planets vary from 0.06 to 317 Earth masses
- Separations of planets range from 0.4 to 38 AU
- Astrometric siganatures of planets at 10 pc have a range from 0.007 to 494 μas, and the Earth has tiny signature of 0.3 μas

Planets of the Solar System

	axis (AU)	period (year)	eccentricity	mass (in Earth)	signature (μas)	RV_sig (m/s)
Mercury	0.387	0.241	0.2056	0.055	0.006	0.01
Venus	0.723	0.615	0.0068	0.815	0.177	0.09
Earth	1.000	1.000	0.0167	1.000	0.300	0.09
Mars	1.523	1.881	0.0934	0.107	0.049	0.01
Jupiter	5.203	11.857	0.0484	317.820	496.085	12.49
Saturn	9.537	29.424	0.0542	95.161	272.265	2.76
Uranus	19.191	83.747	0.0472	14.371	82.738	0.30
Neptune	30.068	163.723	0.0086	17.147	154.673	0.28

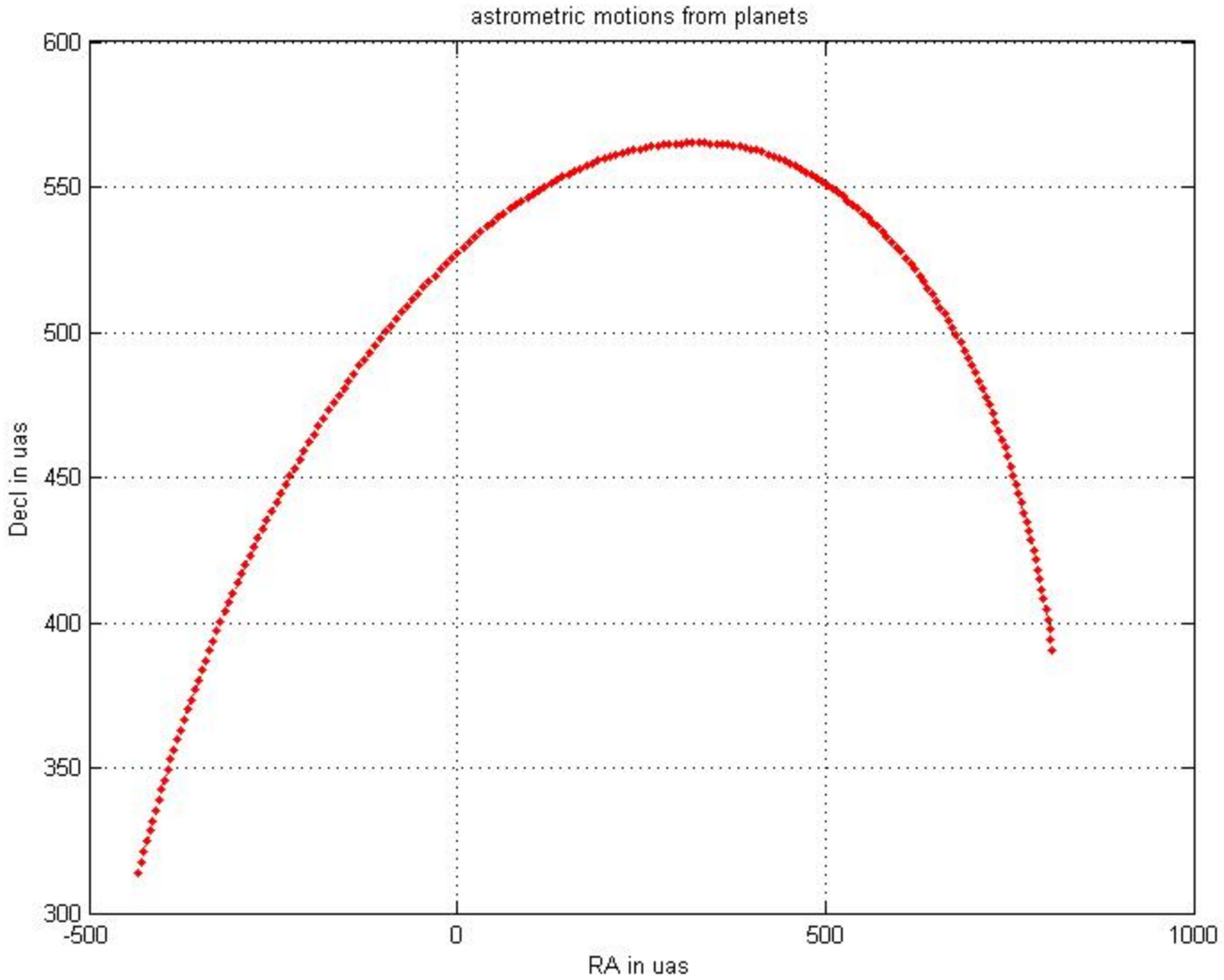
Assume the solar system is located at 10 pc
a is the semi-major axis of orbit in AU;
Astrometric siganature = 0.3*a*mass (μas);

SIM is the only mission to detect the true Earth-like planets

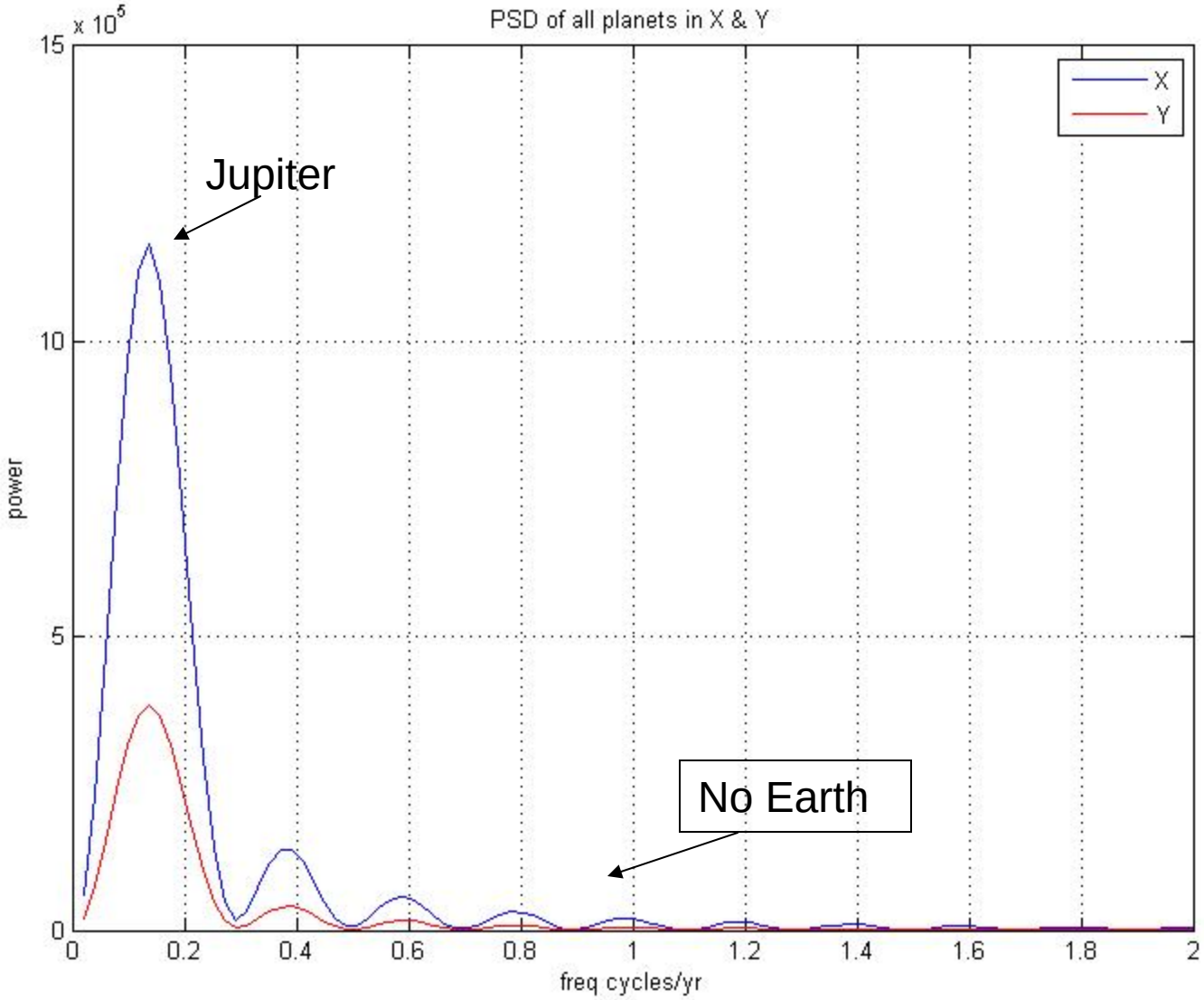
- RV technique is limited by intrinsic stellar activities to 1 m/s
- GAIA is limited by the measurement precision of 7 μas and fixed number of visits
- GAIA can not measure nearby and bright stars
- SIM has narrow- and wide- angle modes for planet exploration and general astrophysics
- SIM can provide precision of 0.5 μas
- SIM can have more than 200 visits in 5 years

Astrometric signatures for solar system

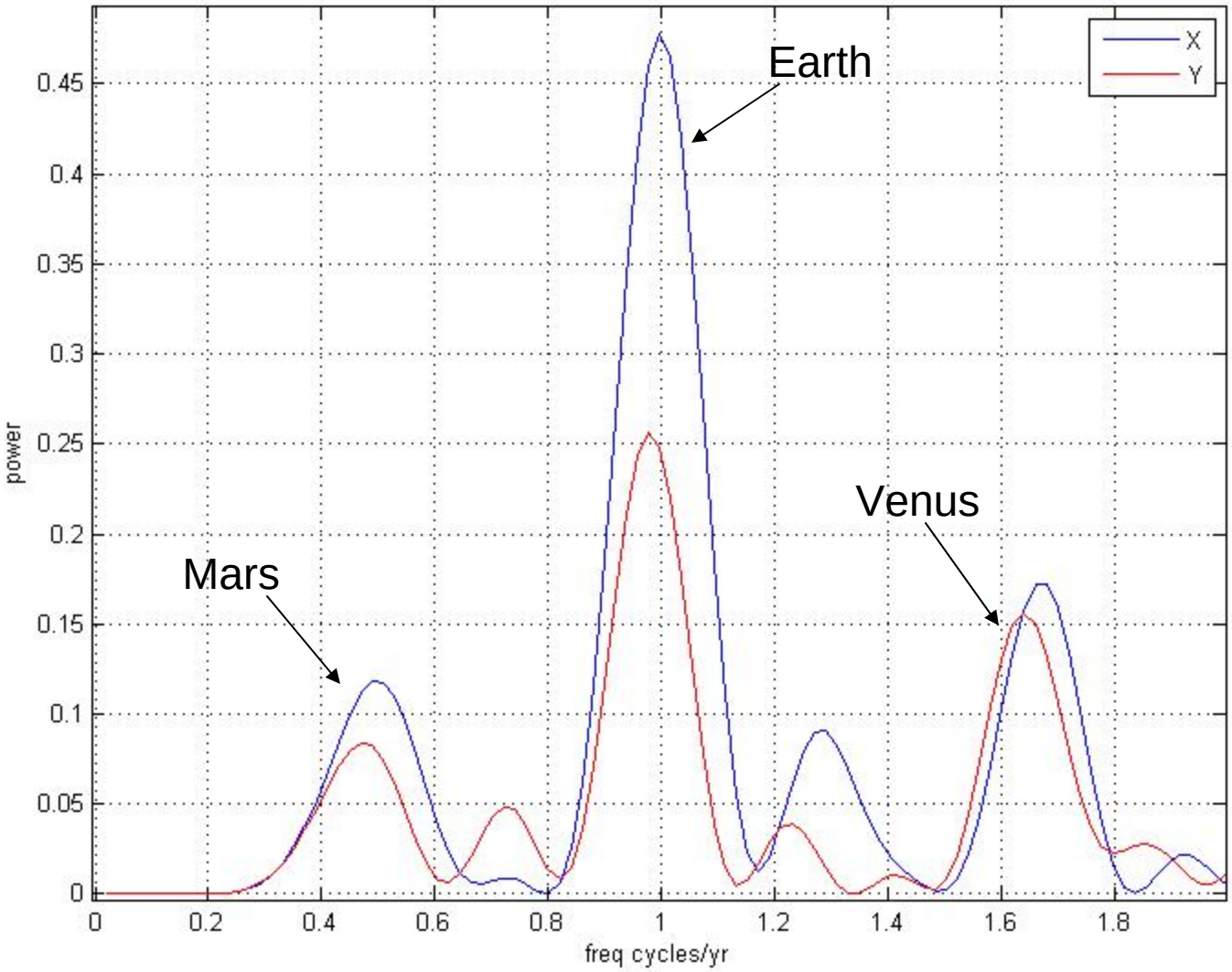
at 10 pc for 5 yr observations



Detection of Jupiter & Saturn



Detection of the Earth



Simulated Observation Results

	a”(uas)		i°		Period (yr)	
	obs	true	obs	true	obs	true
Jupiter	509	496	65	61	7.3	12
Saturn	322	272	73	60	--	29
Venus	0.23	0.18	68	60	0.60	0.7
Earth	0.37	0.30	69	61	0.99	1.0

Preliminary Results of Blind Tests

	signature	period		semi-axis	mass
	μas	days	year	AU	Jupiter
Planet-2	27	80.4	0.22	0.36	0.750
Planet-5	0.296	153.4	0.42	0.56	0.005
Planet-3	1.396	452.9	1.24	1.16	0.012
Planet-4	1.72	555.2	1.52	1.32	0.012
Planet-1	218	2991.4	8.19	4.06	0.536

Notes:

1.The Earth-like planet-5 can be detected.

2. Long-period planet-1 has true period of 9.488yr and mass of 0.315 M_J. Because of 5 yr mission time planet-1 is detected with mass error of 50 %.

3. Planet 6-8 with periods of > 29 yr have not been detected.

4. It is possible to have a false detection of a planet with 2.7 yr period.

Conclusions

- It is challenging task to detect the Earth-like planet, and is more difficult to detect the Earth-like planet in a multiple planet system.
- The SIM mission has a special narrow-angle mode, which can provide accuracy of 0.5 μas for searching the Earth-like planets.
- Simulated observations indicate that it is possible to detect the Earth-like planet when there are Jupiter type planets around.
- Preliminary blind tests demonstrate that it is possible to find the Earth-like planets in multiple planets systems. However, it may have false detection of exoplanet, or miss planet with small signatures.
- Because of limited mission time of 5 years it is important to do further investigations on the influences from outer long period planet

Critical Tasks for SIM Mission

- Increase SNR for detection of Earth-like planets
- Avoid false detection of exoplanets
- Investigate influences of long-period planets for limited life-time of the mission
- Develop robust algorithms for searching Earth-like planets in a multiple planet system
- Carry out special study on detection of exoplanets with period close to one year